HYDROGEOLOGY AND GROUND-WATER QUALITY OF VALLEY FORGE NATIONAL HISTORICAL PARK, MONTGOMERY COUNTY, PENNSYLVANIA

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 96-4120

Prepared in cooperation with the

NATIONAL PARK SERVICE

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by Ronald A. Sloto and B. Craig McManus

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Lemoyne, Pennsylvania
1996

U.S. DEPARTMENT OF THE INTERIOR

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Multiply	by	To obtain
	Length	
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
square mile (mi^2)	2.590	square kilometer
	Volume	
gallon (gal)	3.785	liter
	Temperature	
degree Fahrenheit (°F)	°C=5 / 9 (°F-32)	degree Celsius

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, called Sea Level of 1929.

Abbreviated water-quality units used in report:

- micrograms per liter (µg/L)
- milligrams per liter (mg/L)
- picocuries per liter (pCi/L)
- microsiemens per centimeter at 25 degrees Celsius (µS/cm)

HYDROGEOLOGY AND GROUND-WATER QUALITY OF VALLEY FORGE NATIONAL HISTORICAL PARK, MONTGOMERY COUNTY, PENNSYLVANIA

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ABSTRACT

Valley Forge National Historical Park is just southwest of the Commodore Semiconductor Group (CSG) National Priorities List (Superfund) Site, a source of volatile organic compounds (VOC's) in ground water. The 7.5-square-mile study area includes the part of the park in Lower Providence and West Norriton Townships in Montgomery County, Pa., and surrounding vicinity. The park is underlain by sedimentary rocks of the Upper Triassic age Stockton Formation. A potentiometric-surface map constructed from water levels measured in 59 wells shows a cone of depression, approximately 0.5 mile in diameter, centered near the CSG Site. The cone of depression is caused by the pumping of six public supply wells. A ground-water divide between the cone of depression and Valley Forge National Historical Park provides a hydraulic barrier to the flow of ground water and contaminants from the CSG Site to the park. If pumping in the cone of depression was to cease, water levels would recover, and the ground-water divide would shift to the north. A hydraulic gradient between the CSG Site and the Schuylkill River would be established, causing contaminated ground water to flow to the park.

Water samples were collected from 12 wells within the park boundary and 9 wells between the park boundary and the ground-water divide to the north of the park. All water samples were analyzed for physical properties (field determinations), nutrients, common ions, metals and other trace constituents, and VOC's. Water samples from the 12 wells inside the park boundary also were analyzed for pesticides. Concentrations of inorganic constituents in the water samples did not exceed U.S. Environmental Protection Agency maximum contaminant levels. Very low concentrations of organic compounds were detected in some of the water samples. VOC's were detected in water from 76 percent of the wells sampled; the maximum concentration detected was 5.8 micrograms per liter of chloroform. The most commonly detected VOC was chloroform. The second most commonly detected compound was methyl tert-butyl ether (MTBE), which was detected in water from 24 percent of wells sampled. Several pesticides were detected in water samples collected from within the park boundaries: chlordane, DDD, dieldrin, endrin, heptachlor epoxide, and simazine. Concentrations of the detected pesticides were 0.1 micrograms per liter or less and did not exceed U.S. Environmental Protection Agency maximum contaminant levels.

INTRODUCTION

Valley Forge National Historical Park is a very popular and heavily used recreational area for the large suburban Philadelphia area population. Its significance as an important site during the Revolutionary War attracts many visitors from all over the Nation. The park is just southwest of the Commodore Semiconductor Group (CSG) National Priorities List (Superfund) Site, which is located in the Valley Forge Corporate Center. The CSG Site was constructed in 1970 to manufacture semiconductor chips. The facility included a 250-gallon concrete underground tank for the storage of waste solvent. Leakage from the tank contaminated ground water with volatile organic contaminants (VOC's) (R.F. Weston, Inc., 1992).

A remedial investigation study of the CSG Site by Roy F. Weston, Inc. (1992, p. 4-42 and 4-43) concluded that the plume of VOC's from the CSG Site was moving at a rate of 145 ft per year toward Valley Forge National Historical Park and that the plume had reached the park. Roy F. Weston, Inc. (1992, p. 4-2 and 4-3) also concluded that the CSG Site is not the only source of VOC contamination in the area. The National Park Service (NPS) seeks to acquire additional land in the area. The ground water beneath this land may be contaminated by VOC’s. In addition, several park employees live in houses in the park and rely on ground water as a source of supply. To document ground-water contamination in the park and vicinity, the U.S. Geological Survey in cooperation with the NPS conducted a ground-water study.

Purpose and Scope

This report provides a discussion of ground-water flow and ground-water quality in Valley Forge National Historical Park and vicinity and the effect of VOC’s in ground water from the CSG Site on Valley Forge National Historical Park. It presents a brief description of the hydrology and geology of the area, a potentiometric-surface map based on water levels measured in 59 wells that shows the direction of ground-water flow, and the results of water-quality analyses. This information is necessary to determine the effect of the CSG Site on the park. Water samples from 21 wells were analyzed for physical properties (field determinations), nutrients, common ions, metals and other trace constituents, and VOC’s. Water samples from 12 wells inside the park boundary also were analyzed for organochlorine, organophosphorus, and organonitrogen pesticides.

Location and Physiography

The study area (fig. 1) includes the part of Valley Forge National Historical Park in Lower Providence and West Norriton Townships in Montgomery County, Pa., and surrounding vicinity. The 7.5-mi^2 study area is drained by small tributaries to the Schuylkill River, which forms the southern boundary of the study area, and Perkiomen Creek, which forms the western boundary of the study area. Valley Forge National Historical Park is underlain by sedimentary rocks of the Upper Triassic age Stockton Formation in the Triassic Lowlands Section of the Piedmont Physiographic Province. The topography is flat to rolling.

Climate

The study area has a humid, modified continental climate characterized by warm summers and moderately cold winters. The normal (1961-90) mean annual temperature at Phoenixville is 51.7°F. The normal (1961-90) mean temperature for January, the coldest month, is 28°F, and the normal mean temperature for July, the warmest month, is 73.8°F. The normal (1961-90) annual precipitation at Phoenixville is 42.56 in. (Owenby and Ezell, 1992). Precipitation is about evenly distributed throughout the year, with slightly more occurring during the warmer months because of localized thunderstorms.

Well-Numbering System

The well-numbering system used in this report consists of a county abbreviation prefix followed by a sequentially-assigned number. The prefix MG denotes a well located in Montgomery County. Data on wells sampled for water-quality analysis or used for water-level measurements for this study are listed in table 10, and the locations of the wells are shown on figure 2.

Previous Investigations

The geology and hydrology of the Stockton Formation in southeastern Pennsylvania was described by Rima and others (1962). Biesecker and others (1968) described the water resources of the Schuylkill River Basin. The ground-water resources of Montgomery County was summarized by Newport (1971). Montgomery County is included on the geologic map of Lyttle and Epstein (1987). A remedial investigation and feasibility study was done for the CSG Site by Roy F. Weston, Inc. (1992).

Acknowledgments

The authors gratefully acknowledge the many individuals and corporations that permitted access to their wells for water-level measurements and water samples. The authors especially thank Brian Lambert of the National Park Service and the Audubon Water Company for their assistance.

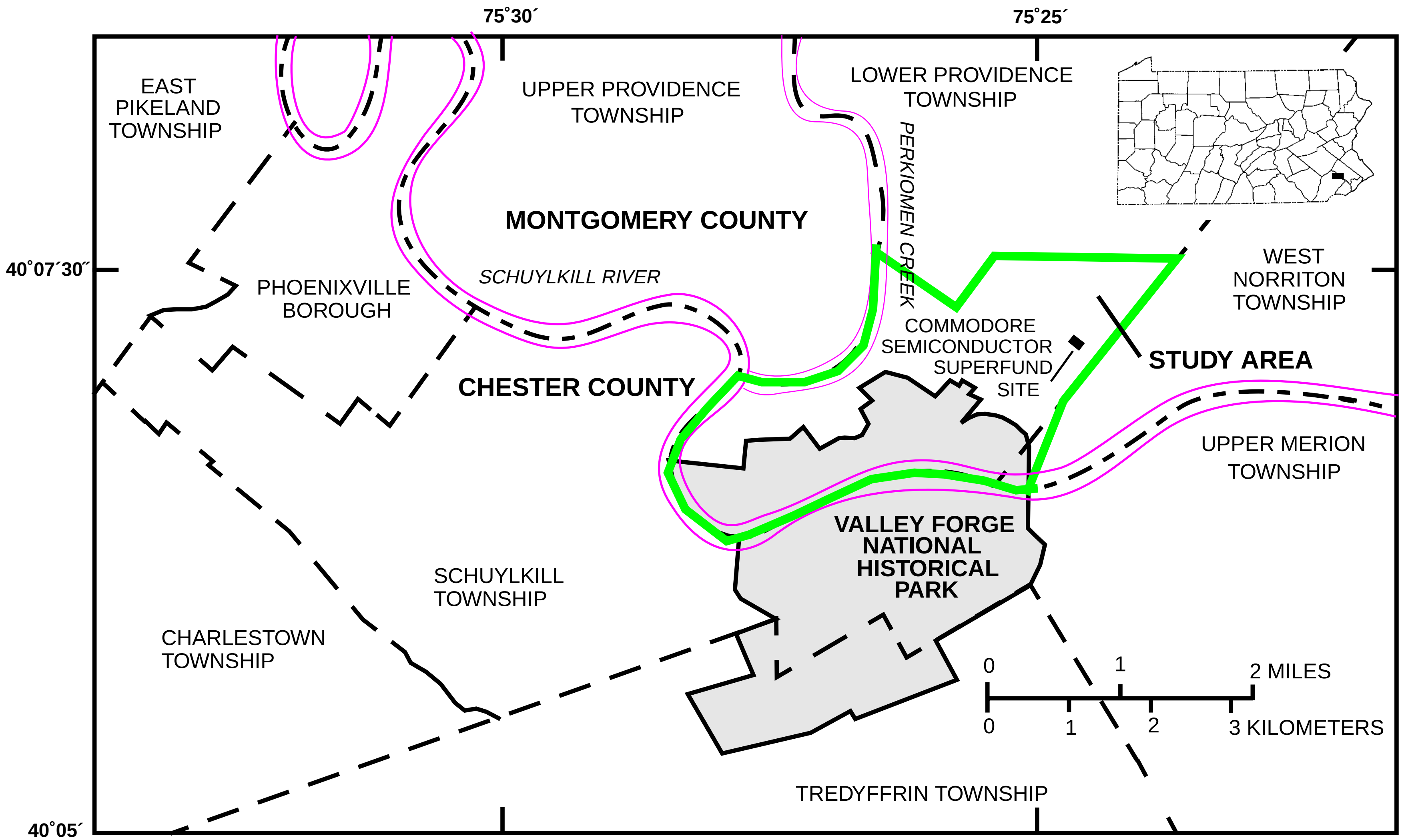
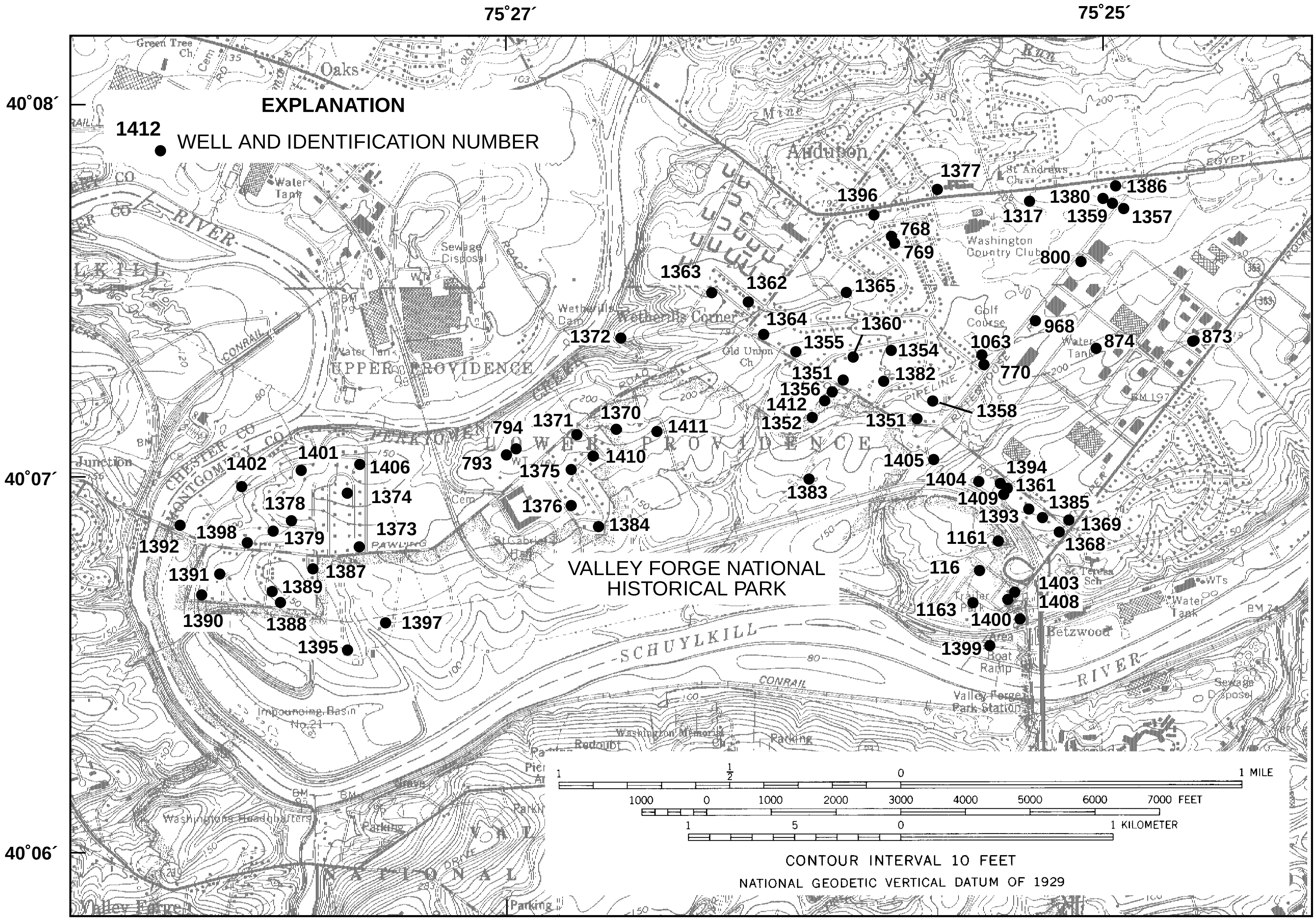


Figure 1. Location of study area.



Base from U.S. Geological Survey Collegeville 1:24,000 1983 and Valley Forge 1:24,000 1981

Figure 2. Location of wells in Valley Forge National Historical Park and vicinity, Montgomery County, Pa.

HYDROGEOLOGY

The ground-water-flow system is determined largely by geology. In the study area, water occupies most of the open space in the rock below the water table. This constitutes the ground-water reservoir. Most ground water is stored in the weathered rock near the land surface.

Geology

The study area is underlain by the Stockton Formation of Upper Triassic age, which is the oldest of the Newark Basin sediments and forms the basal unit. The Stockton rests unconformably on rocks of Paleozoic and Precambrian age. Sedimentation in the Newark Basin began with an influx of arkosic detritus from uplifted crystalline rocks to the south not far from the present day southern basin margin (Glaeser, 1966). The Stockton Formation includes alluvial fans, fluvial and lacustrine sandstones, and fluvial and near-shore lacustrine mudstones and siltstones (Turner-Peterson and Smoot, 1985). Near the southern margin, the Stockton contains laterally coalescing alluvial fans deposited by well-established streams. Thick, poorly defined upward fining cycles possibly were deposited by large, perennial, meandering rivers. The rocks contain channels, ripple marks, mudcracks, crossbeds, lenses, pinch-and-swell structures, and minor burrows. Rapid lithologic changes are characteristic of the Stockton Formation. Single beds may grade along strike from fine grained to coarse grained in a few yards (Willard and others, 1959, p. 65). Stockton lithology is diverse, and the rocks differ widely in bedding, texture, and color. The rocks of the Stockton are characterized by their high arkose content.

At Betzwood, which is in the southeastern part of the study area, the Stockton Formation strikes east-west and dips 15° to the north (Rima and others, 1962, plate 2). The lower part of the study area is underlain by the lower arkose member of the Stockton; the upper part of the study area is underlain by the middle arkose member of the Stockton (Rima and others, 1962, plate 2). The lower arkose member of the Stockton Formation is estimated by Rima and others (1962, p. 11) to be 550 ft thick at Phoenixville and to comprise 23 percent of the formation thickness. The lower arkose member appears to take the form of an alluvial fan in the study area and consists chiefly of gray, reddish-brown, and pale orange coarse- and very coarse-grained sandstone and some conglomerate. Shale and thin beds of fine- and medium-grained arkosic sandstone are locally present.

The middle arkose member of the Stockton Formation is estimated by Rima and others (1962, p. 14) to be 1,700 ft thick at Phoenixville and to comprise about 75 percent of the formation thickness. The middle arkose member consists chiefly of pale brown to pale red, gray, and pale orange fine- and medium-grained arkosic sandstone and interbedded shale. In many places, shale is more abundant than sandstone. Thick beds of shale and siltstone are abundant in the upper part of the member. Siltstones and shales are fairly weak, slightly sandy, and usually micaceous. Ripple marks and mudcracks are common.

Hydrology

The rocks of the Stockton Formation form a complex, heterogeneous, multiaquifer system. This aquifer system comprises a series of gently dipping lithologic units with different hydraulic properties. The ground-water system can be visualized as a series of beds with a relatively high transmissivity separated by beds with a relatively low transmissivity. These beds, from a few inches to a few feet thick, act as a series of alternating aquifers and confining or semiconfining units that form a leaky, multiaquifer system. Each bed generally has different hydraulic properties, and permeability commonly differs from one bed to another.

In the Stockton Formation, ground water in the weathered zone moves through intergranular openings that have formed as a result of weathering. In some places, permeability of the weathered zone may be poor because of a high percentage of clay derived from weathering of siltstone and shale. Ground water in the unweathered zone mainly moves through a network of interconnected secondary openings—fractures, bedding planes, and joints. Beds within the Stockton Formation are hydraulically connected by high-angle joints that cross each other at various angles.

In general, the coarse-grained (sandstone and conglomerate) units are the principal water-bearing units, but some of the finer-grained (siltstone and shale) units also contain water-bearing openings. However, because of the softness and fine grain size of the siltstone and shale units, water-bearing openings tend to be clogged. In addition, the soft siltstone and shale beds deform without breaking under stress and, as a result, have lower permeability than the harder sandstone and conglomerate beds, which tend to develop fractures and joints and, thus, are more permeable.

Some water-bearing openings may be slightly enlarged by circulating ground water, which has decomposed and disintegrated mineral constituents in the walls of fractures. Any primary porosity that may have originally existed has been almost eliminated by compaction and cementation. Some water may move through intergranular openings in the rock below the weathered zone where the cement has been removed and the permeability has increased, but this generally is restricted to a few coarse-grained sandstone and conglomerate beds.

Ground water is unconfined in the shallower part of the aquifer and confined or semiconfined in the deeper part of the aquifer. Ground water under confined conditions is under pressure greater than atmospheric. Differences in the ratio of vertical to horizontal hydraulic conductivity, as well as differences in vertical hydraulic conductivity within and among lithologic units, create confining conditions.

Nearly all deep wells in the Stockton Formation are open to several water-bearing zones and are multiaquifer wells. Each water-bearing zone usually has a different hydraulic head. The hydraulic head in a deep, open-hole well is the composite of the heads in the several water-bearing zones penetrated. This can cause water levels in some wells to be different than water levels in adjacent wells of different depths. Where differences in hydraulic head exist between water-bearing zones, water in the well bore flows under nonpumping conditions in the direction of decreasing head.

A potentiometric-surface map (fig. 3) was constructed from water levels measured in 59 wells in May and June of 1994. In most cases, the water-level elevations represent composite heads from several water-bearing zones in each well. However, because the difference in head between water-bearing zones is commonly a few feet or less and the contour interval of the map is 10 ft, the map provides a representation of the potentiometric surface. In general, ground-water flow is perpendicular to the potentiometric-surface contours, and ground water flows from higher to lower elevation.

The potentiometric-surface map shows a cone of depression in the potentiometric surface, approximately 0.5 mi in diameter, centered near the CSG Site. The cone of depression is caused by the pumping of six public supply wells: MG-770 (Audubon Water Company 3), MG-1063 (Audubon Water Company 5), MG-873 (Valley Forge Corporate Center 1), MG-874 (Valley Forge Corporate Center 2), MG-800 (Valley Forge Corporate Center 3), and MG-968 (Valley Forge Corporate Center 4). The water levels in wells MG-873 and MG-1063, which were pumping, could not be measured. Ground water in the cone of depression flows toward and discharges to the pumping wells. West of Audubon Road, the configuration of the potentiometric surface mimics the land surface topography and parallels the strike of the bedrock. A ground-water mound that parallels strike and coincides with the local topographic high lies southwest of Audubon Road.

The pumping wells have caused a ground-water divide to form between the cone of depression and Valley Forge National Historical Park (fig. 3). The ground-water divide acts as a hydraulic barrier to the flow of ground water and contaminants from the CSG Site to the park. Ground water to the north of the divide discharges to Perkiomen Creek, ground water to the south of the divide discharges to the Schuylkill River, and ground water in the cone of depression discharges to pumping wells in the cone of depression. If pumping ceases within the cone of depression, ground-water levels would recover, and the ground-water divide would shift northward toward the topographic high and ground-water mound south of Egypt Road. If this shift were to occur, a hydraulic gradient would be established between the CSG Site and the Schuylkill River, the point of ground-water discharge. Contaminated ground water flows down the hydraulic gradient toward the park.

Near Betzwood, water-elevations are 62 ft above sea level in well MG-1399, 60 ft above sea level in well MG-1400, and 62 ft above sea level in well MG-1163. These water-level elevations are at or below the elevation of the Schuylkill River. Near the confluence of Perkiomen Creek and the Schuylkill River, the water-level elevation, 70 ft above sea level in well MG-1402, is close to the elevation of the Schuylkill River. These wells may be inducing inflow from the Schuylkill River along strike.

GROUND-WATER QUALITY

As water moves through the hydrologic cycle, chemical and mineral substances from the atmosphere, the soil, and rocks are dissolved. The type and quantity of these dissolved substances constitute the quality of ground water. Anthropogenic activities also add substances to ground water and may affect its quality. Statistics presented below are based on ground-water samples from 21 wells collected for this study (fig. 4). Water samples were collected from 12 wells within the park boundary and 9 wells between the park boundary and the ground-water divide to the north of the park. All wells inside of the park boundary where permission could be obtained were sampled; some of the land within the park boundary is privately held. The wells sampled outside the park boundary were selected because of known or suspected ground-water contamination.

All water samples were analyzed for physical properties (field determinations), nutrients, common ions, metals and other trace constituents, and VOC's. Water samples from the 12 wells inside the park boundary also were analyzed for pesticides. Ten wells inside the park boundary and wells in an area where cyanide was reported to have been detected in ground water were sampled for cyanide. Cyanide was not detected in any water sample.

Field Determinations

Field determinations include pH, specific conductance, alkalinity, dissolved oxygen, and temperature. These determinations are made when a water sample is collected because these properties are unstable and may be affected by storage (Hem, 1985). Results of the field determinations are given in table 1.

pH is a measurement of hydrogen ion activity in water. pH is expressed in logarithmic units, and a pH of 7 is considered neutral. Water with a pH less than 7 is acidic; water with a pH greater than 7 is basic. The median pH of water from the sampled wells was 6.6, and pH ranged from 5.2 to 8.2.

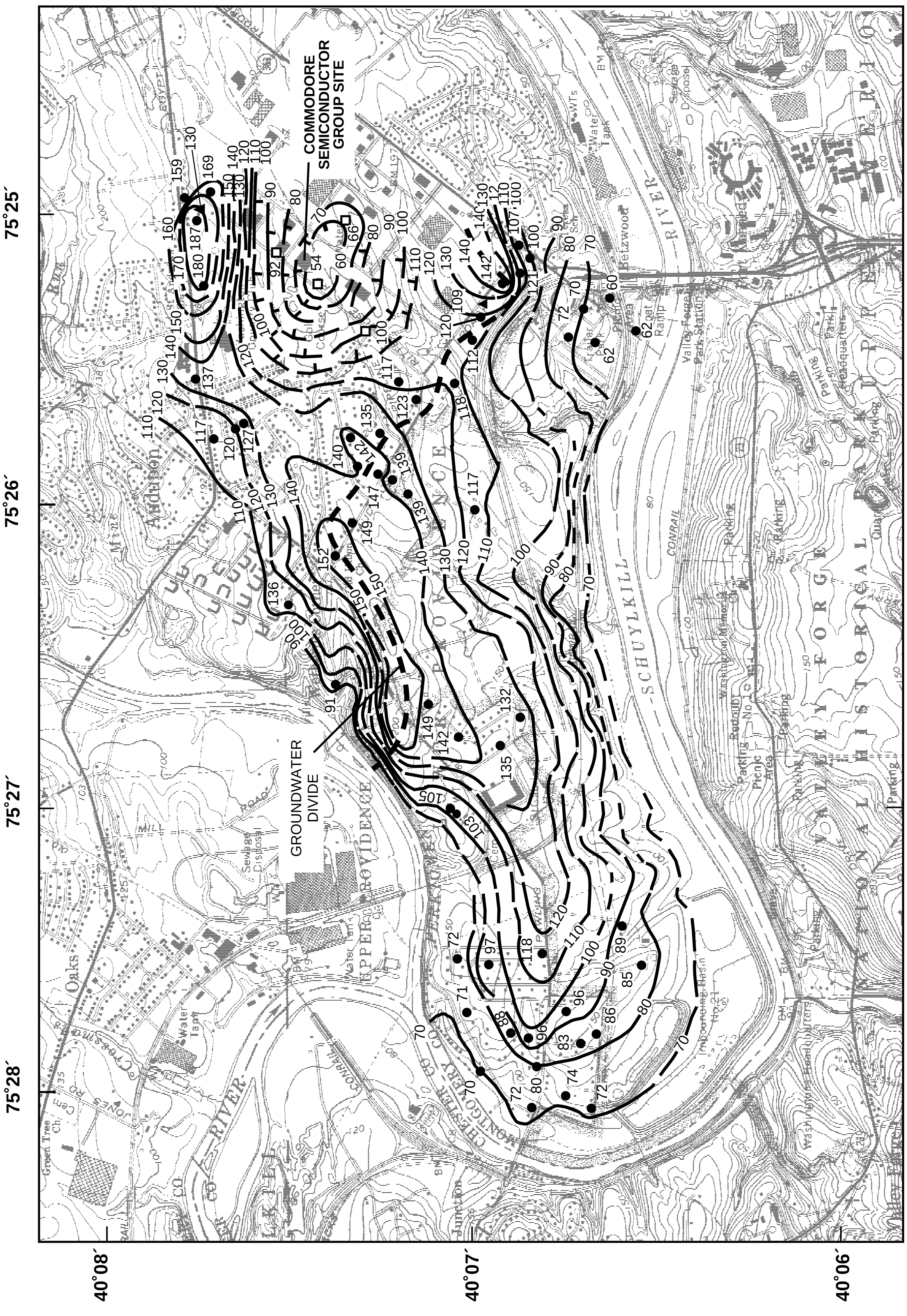
Specific conductance is a measurement of the ability of water to conduct an electric current. It is expressed in units of microsiemens per centimeter at 25°C. The median specific conductance of water from the sampled wells was 480 µS/cm, and specific conductance ranged from 215 to 900 µS/cm. In dilute solutions, specific conductance is directly related to the concentration of total dissolved solids (TDS), and TDS concentrations can be estimated from specific-conductance measurements. The TDS concentration of a water sample from the study area can be estimated by multiplying the specific conductance by 0.56, the median ratio of specific conductance to TDS of the 21 samples.

The alkalinity of water is the capacity for solutes it contains to react with and neutralize acid (Hem, 1985, p. 106). Alkalinity is produced by dissolved carbon dioxide, bicarbonate, and carbonate and is expressed in terms of an equivalent amount of calcium carbonate. The median alkalinity of water from the sampled wells was 117 mg/L as $CaCO_3$, and alkalinity ranged from 15 to 172 mg/L as $CaCO_3$.

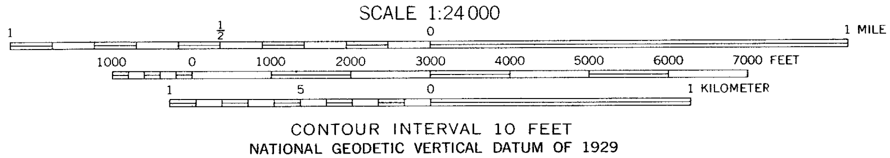
The median concentration of dissolved oxygen of water from the sampled wells was 5.0 mg/L, and dissolved oxygen concentrations ranged from 0.4 to 9.6 mg/L. Low concentrations of dissolved oxygen in water from some wells may be due to abundant oxidizable minerals, such as pyrite, or biological degradation of organic compounds, which deplete the available oxygen.

Inorganic Constituents

Common ions analyzed and reported are calcium, chloride, fluoride, magnesium, potassium, silica, sodium, and sulfate. Nutrient species analyzed and reported are nitrate, nitrite, ammonia, phosphorus,



Base from U.S. Geological Survey Collegeville 1:24,000 1983 and Valley Forge 1:24,000 1981



EXPLANATION

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POTENTIOMETRIC CONTOUR--Shows altitude of potentiometric surface as defined by measu water levels. Dashed where approximately located. Hachured contour lines indicate depression the potentiometric surface due to pumping. Contour interval is 10 feet. Altitude is in feet above t National Geodetic Vertical Datum of 1929

GROUND-WATER DIVIDE

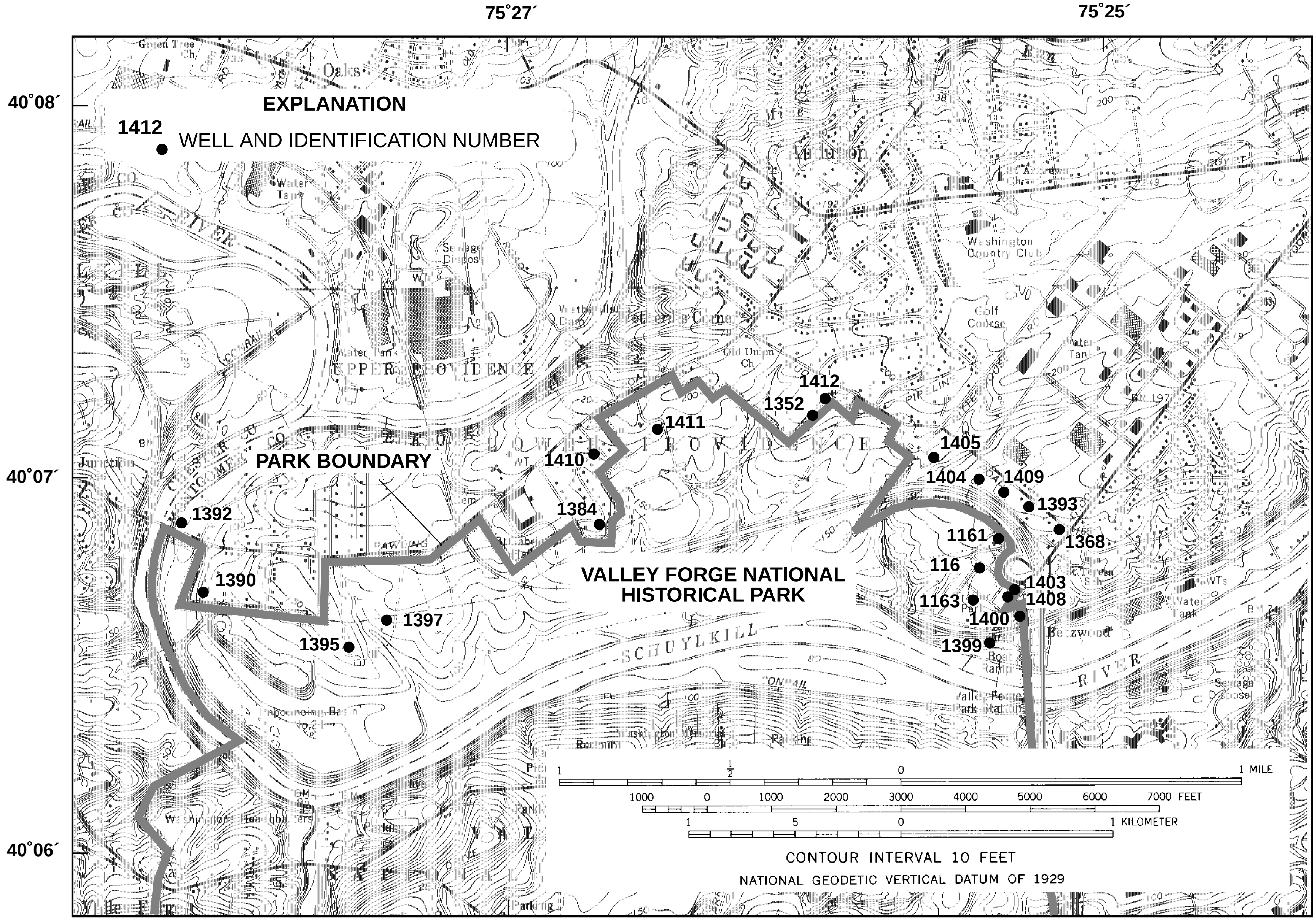
SITE USED FOR WATER-LEVEL MEASUREMENT--Symbol gives location of site. Number is a tude of a static water-level measurement in a drilled well in feet above the National Geodetic Ve cal Datum of 1929

72 ● Altitude of static water level measured in a drilled well

54 □ Altitude of water level measured in a pumping public supply well

109 ▲ Altitude of water level measured in a monitor well screened in a deep water-bearing zone. These d were not used to contour the potentiometric surface and are included for information only

Figure 3. Altitude and configuration of the potentiometric surface, Valley Forge National Historical park and vicinity, Montgomery County, Pa., May and June 1994.



Base from U.S. Geological Survey Collegeville 1:24,000 1983 and Valley Forge 1:24,000 1981

Figure 4. Location of sampled wells in Valley Forge National Historical Park and vicinity, Montgomery County, Pa

and orthophosphate. Trace constituents analyzed and reported are aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, uranium, and zinc. Other constituents analyzed and reported are cyanide and radon-222. Concentrations are reported in milligrams per liter, which is equivalent to parts per million, and micrograms per liter, which is equivalent to parts per billion.

Table 1. Results of field determinations of ground water in Valley Forge National Historical park and vicinity, Montgomery County, Pa.

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate]

Well identification number	Date	pH (standard units)	Specific conductance (µS/cm)	Water temperature (°C)	Alkalinity (mg/L as $CaCO_3$)	Dissolved oxygen (mg/L)
1161	09-01-94	6.9	740	13.0	172	5.0
1162	08-30-94	6.6	680	13.0	154	4.4
1163	09-01-94	5.7	550	14.0	119	3.0
1352	09-13-94	7.0	325	13.0	97	9.0
1368	08-29-94	6.9	900	17.0	161	5.0
1384	08-24-94	6.5	550	14.0	108	4.2
1390	08-30-94	6.2	215	14.0	47	7.8
1392	08-29-94	7.0	470	14.0	130	7.6
1393	09-14-94	5.7	525	14.0	28	5.0
1395	08-16-94	6.4	228	13.0	48	8.6
1397	08-16-94	7.6	265	14.0	83	8.4
1399	08-18-94	6.3	720	15.0	138	4.4
1400	08-22-94	8.2	426	13.0	126	.4
1403	08-25-94	6.3	460	15.0	114	4.6
1404	09-14-94	7.6	480	16.0	117	5.8
1405	09-08-94	7.4	580	12.0	124	3.0
1408	08-17-94	5.6	240	15.0	15	9.6
1409	08-24-94	6.7	690	13.0	156	5.1
1410	08-31-94	5.2	650	15.0	30	2.0
1411	09-07-94	6.3	380	15.0	95	5.6
1412	09-15-94	6.9	425	12.0	150	6.4

Common Ions

Common ions dissolved from soil and rock constitute most of the dissolved solutes in ground water; some solutes are dissolved in precipitation. Common ions, in order of decreasing concentration on the basis of median concentrations in samples collected for this study, in the ground water of Valley Forge National Historical Park and vicinity are calcium (46 mg/L), chloride (43 mg/L), silica (26 mg/L), sulfate (25 mg/L), sodium (18 mg/L), magnesium (12 mg/L), nitrate (4.4 mg/L), and potassium (1.3 mg/L). Complete laboratory analyses for common ions are given in table 2. Nitrate is discussed in the following section.

The U.S. Environmental Protection Agency (USEPA) has set maximum contaminant levels (MCL's) and secondary maximum contaminant levels (SMCL's) for some constituents in drinking water (table 3). MCL's usually are set because elevated concentrations of these constituents may cause adverse health effects. SMCL's usually are set for aesthetic reasons; elevated concentrations of these constituents may impart an undesirable taste or odor to water.

The median TDS concentration of water from sampled wells was 298 mg/L, and TDS concentrations ranged from 124 to 506 mg/L. The USEPA SMCL for TDS concentration in drinking water is 500 mg/L (table 3). Water from 1 (well MG-1368) of the 21 wells sampled exceeded the USEPA SMCL for TDS.

Table 2. Results of chemical analyses for common ions, cyanide, and radon-222 in ground water in Valley Forge National Historical Park and vicinity, Montgomery County, Pa.

[mg/L, milligrams per liter; °, degree Celsius; µg/L, microgram per liter; pCi/L, picoCuries per liter; <, less than; --, no data]

Well identification number	Date	Calcium, dissolved (mg/L as Ca)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F	Magnesium, dissolved (mg/L as Mg)	Potassium, dissolved (mg/L as K)	Silica, dissolved (mg/L as SiO_2)
1161	09-01-94	100	87	<0.1	12	1.4	24
1162	08-30-94	86	95	<.1	16	1.4	28
1163	09-01-94	54	68	<.1	17	1.3	26
1352	09-13-94	36	13	<.1	9.3	.80	28
1368	08-29-94	110	150	<.1	12	1.4	23
1384	08-24-94	60	64	<.1	16	1.0	26
1390	08-30-94	20	18	<.1	4.3	.50	28
1392	08-29-94	68	40	<.1	6.8	.60	30
1393	09-14-94	38	88	<.1	14	1.7	23
1395	08-16-94	23	11	<.1	3.4	.80	26
1397	08-16-94	35	6.6	<.1	4.8	.70	24
1399	08-18-94	45	100	<.1	38	1.3	16
1400	08-22-94	17	28	.5	5.7	4.5	8.9
1403	08-25-94	46	42	<.1	16	1.4	29
1404	09-14-94	66	43	<.1	11	1.3	22
1405	09-08-94	72	62	<.1	17	1.1	21
1408	08-17-94	15	21	<.1	6.3	1.3	27
1409	08-24-94	84	76	<.1	13	1.4	24
1410	08-31-94	45	150	<.1	16	1.6	37
1411	09-07-94	31	26	<.1	13	2.8	34
1412	09-15-94	60	16	<.1	12	1.2	25

Well identification number	Date	Sodium, dissolved (mg/L as Na)	Sulfate, dissolved (mg/L as SO_4)	Solids, residue at 180 °C, dissolved (mg/L)	Radon-222, dissolved (pCi/L)	Cyanide, total (µg/L as CN)
1161	09-01-94	19	25	482	1,100	<0.01
1162	08-30-94	21	26	366	1,200	<.01
1163	09-01-94	21	14	298	3,000	<.01
1352	09-13-94	10	19	214	1,300	<.01
1368	08-29-94	48	39	506	790	<.01
1384	08-24-94	17	31	328	5,000	--
1390	08-30-94	11	6.0	126	1,900	--
1392	08-29-94	9.4	13	326	810	--
1393	09-14-94	36	54	316	800	<.01
1395	08-16-94	11	2.9	124	830	--
1397	08-16-94	5.8	6.1	158	740	--
1399	08-18-94	31	42	384	840	<.01
1400	08-22-94	59	29	236	3,200	<.01
1403	08-25-94	17	17	266	1,900	<.01
1404	09-14-94	11	26	292	2,300	<.01
1405	09-08-94	15	59	344	1,200	<.01
1408	08-17-94	15	29	138	830	--
1409	08-24-94	26	38	392	840	<.01
1410	08-31-94	38	10	356	1,300	--
1411	09-07-94	18	20	196	1,600	<.01
1412	09-15-94	14	19	270	1,500	<.01

Table 3. U.S. Environmental Protection Agency maximum contaminant levels and secondary maximum contaminant levels for selected constituents in drinking water

[From U.S. Environmental Protection Agency (1993); concentrations in micrograms per liter except as indicated; mg/L, milligrams per liter; pCi/L, picoCuries per liter; --, no established limit]

Constituent	Maximum contaminant level	Secondary maximum contaminant level
Inorganic		
Antimony	6	--
Arsenic	50	--
Barium (mg/L)	2	--
Beryllium	4	--
Cadmium	5	--
Chromium, total	100	--
Chloride (mg/L)	--	250
Copper (mg/L)	--	1
Fluoride (mg/L)	4	2
Iron	--	300
Lead	[1]15	--
Manganese	--	50
Mercury	2	--
Nickel	100	--
Nitrate as nitrogen (mg/L)	10	--
Nitrite as nitrogen (mg/L)	1	--
Selenium	50	--
Silver	--	100
Sulfate (mg/L)	--	250
Total dissolved solids (mg/L)	--	500
Uranium (pCi/L)	20	--
Zinc (mg/L)	--	5
Pesticides		
Alachlor	2	--
Atrazine	3	--
Chlordane	2	--
Endrin	2	--
Heptachlor	.4	--
Heptachlor epoxide	.2	--
Lindane	.2	--
Methoxychlor	40	--
Simazine	4	--
Toxaphene	3	--
Volatile organic compounds		
Benzene	5	--
Bromodichloromethane	100	--
Bromoform	100	--
Carbontetrachloride	5	--
Chloroform	100	--
1,2-Dichloroethane	5	--
1,1-Dichloroethylene	7	--
cis-1,2,-Dichloroethylene	70	--
trans-1,2,-Dichloroethylene	100	--
1,2-Dichloropropane	5	--
Ethylbenzene	700	--
Methylene chloride	5	--
Styrene	100	--
Tetrachloroethylene	5	--
Toluene	1,000	--
1,1,1-Trichloroethane	200	--
1,1,2-Trichloroethane	5	--
1,2,4-Trichlorobenzene	70	--
Trichloroethylene	5	--
Vinyl chloride	2	--
Xylenes	10,000	--
Other organic compounds		
Polychlorinated biphenyls	.5	--

[1]Action level.

Most chloride in ground water is dissolved from natural sources. The median concentration of chloride in water from the sampled wells is 43 mg/L, and chloride concentrations ranged from 6.6 to 150 mg/L. Elevated concentrations of chloride may be caused by anthropogenic sources, such as input from highway deicing salt, fertilizers, and septic systems. Water from well MG-1368, near the intersection of Audubon and Trooper Roads, has elevated concentrations of chloride (150 mg/L), calcium (110 mg/L), and sodium (48 mg/L), probably from NaCl and $CaCl_2$, which are used as highway deicing salts. Deicing salt also may have caused the high chloride concentrations in water from wells MG-1410 (150 mg/L), MG-1399 (100 mg/L), MG-1162 (95 mg/L), MG-1393 (88 mg/L), and MG-1161 (87 mg/L); water from these wells also has elevated concentrations of sodium.

Nutrients

Essential nutrients for plant and animal growth include species of nitrogen and phosphorus. Nitrogen is found in water principally as nitrate (NO_3), nitrite (NO_2), and ammonia (NH_4). Phosphorus is found in water principally as a form of the orthophosphate ion species. The orthophosphate species are the most thermodynamically stable of the P^{5+} forms likely to occur in natural waters (Hem, 1985, p. 127). The presence of elevated concentrations of nutrients is usually an indicator of ground-water contamination. Nutrient sources include fertilizers, animal wastes, and effluent from sewage treatment or on-site septic systems. Complete laboratory analyses for nutrients are given in table 4.

Nitrate is the most prevalent nitrogen species in ground water (table 4). No nitrite was detected; therefore, the concentrations of nitrite plus nitrate listed in table 4 are equal to the concentrations of nitrate. The median concentration of nitrate in water from the sampled wells was 4.4 mg/L, and nitrate concentrations ranged from 0.06 to 6.5 mg/L. No concentrations of nitrate exceed the USEPA MCL. Ammonia and phosphorus species are present in concentrations less than 0.14 mg/L.

Table 4. Results of chemical analyses for nutrients in ground water in Valley Forge National Historical Park and vicinity, Montgomery County, Pa.

[mg/L, milligram per liter; NO_2, nitrite; NO_3, nitrate; <, less than; --, no data]

Well identification number	Date	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, $NO_2 + NO_3$, dissolved (mg/L as N)	Phosphorus, dissolved (mg/L as P)	Phosphate, ortho, dissolved (mg/L as PO_4)
1161	09-01-94	0.02	<0.01	3.3	0.09	0.07
1162	08-30-94	<.01	<.01	3.6	.10	.10
1163	09-01-94	.02	<.01	4.2	--	.12
1352	09-13-94	.01	<.01	2.6	.06	.06
1368	08-29-94	.01	<.01	3.3	.06	.06
1384	08-24-94	.01	<.01	4.5	.10	.11
1390	08-30-94	<.01	<.01	5.2	.06	.06
1392	08-29-94	.01	<.01	5.8	.08	.08
1393	09-14-94	<.01	<.01	4.4	.11	.12
1395	08-16-94	<.01	<.01	6.3	.06	.06
1397	08-16-94	<.01	<.01	6.5	.10	.09
1399	08-18-94	<.01	<.01	2.6	.04	.05
1400	08-22-94	.02	<.01	.06	<.01	<.01
1403	08-25-94	<.01	<.01	3.6	.10	.09
1404	09-14-94	.01	<.01	3.9	.06	.06
1405	09-08-94	.02	<.01	1.6	.06	.06
1408	08-17-94	<.01	<.01	5.9	.07	.07
1409	08-24-94	.01	<.01	5.7	.09	.09
1410	08-31-94	.02	<.01	4.8	.03	.03
1411	09-07-94	.02	<.01	5.2	.14	.14
1412	09-15-94	.01	<.01	4.5	.07	.08

Metals and Other Trace Constituents

Metals, such as iron, lead, and manganese, and other trace constituents, such as arsenic, typically are present in low concentrations in water from wells in Valley Forge National Historical Park and vicinity. Most metals and other trace constituents in natural ground water are leached from the soil or dissolved from the underlying bedrock in minute quantities by circulating ground water. Some are present in precipitation. Copper, lead, and zinc in tap water may be leached from household plumbing systems.

Metals and other trace constituents, such as arsenic and selenium, typically are present in concentrations less than 1 µg/L in natural waters. Some constituents, such as iron and manganese, are commonly determined and are usually present. Other constituents, such as beryllium and silver, are not commonly determined, and, if present, concentrations generally are below the detection limit of analytical instruments.

Laboratory analyses for metals and other trace constituents in ground water are given in table 5. Data for most metals and trace constituents are difficult to statistically evaluate because concentrations commonly are below detection limits. The concentrations of constituents in table 5 represent natural background concentrations. The constituents listed in table 5 do not pose a ground-water quality problem in Valley Forge National Historical Park and vicinity. The USEPA has established MCL's and SMCL's for some of these constituents, except for lead, in drinking water (table 3). None of the constituents listed in table 5 exceed USEPA MCL's or SMCL's. Antimony, beryllium, cobalt, mercury, and silver were not detected in any water sample. For lead, an action level of 15 µg/L has been established by the USEPA (U.S. Environmental Protection Agency, 1991). The action level, as defined by the USEPA, means that a public water purveyor must take corrective action if the concentration of lead is above 15 µg/L in more than 10 percent of tap water samples collected during any monitoring period. The USEPA action level of 15 µg/L for lead was not exceeded in water from the 21 wells sampled.

Table 5. Results of chemical analyses for metals and trace constituents in ground water in Valley Forge National Historical Park and vicinity, Montgomery County, Pa.

[µg/L, microgram per liter; <, less than]

Well identification number	Date	Aluminum, dissolved (µg/L as Al)	Antimony, dissolved (µg/L as Sb)	Arsenic, dissolved (µg/L as As)	Barium, dissolved (µg/L as Ba)	Beryllium, dissolved (µg/L as Be)	Cadmium, dissolved (µg/L as Cd)	Chromium, dissolved (µg/L as Cr)
1161	09-01-94	1	<1	1	450	<1	<1	2
1162	08-30-94	1	<1	1	250	<1	<1	2
1163	09-01-94	2	<1	<1	370	<1	<1	3
1352	09-13-94	2	<1	<1	140	<1	<1	1
1368	08-29-94	2	<1	<1	280	<1	<1	2
1390	08-30-94	2	<1	<1	130	<1	<1	4
1392	08-29-94	1	<1	<1	710	<1	<1	2
1393	09-14-94	4	<1	<1	130	<1	<1	3
1395	08-16-94	2	<1	<1	160	<1	<1	5
1397	08-16-94	2	<1	1	260	<1	<1	2
1399	08-18-94	2	<1	<1	170	<1	<1	9
1400	08-22-94	6	<1	<1	85	<1	<1	3
1403	08-25-94	4	<1	<1	300	<1	<1	5
1404	09-14-94	3	<1	<1	350	<1	<1	1
1405	09-08-94	1	<1	2	77	<1	<1	2
1408	08-17-94	4	<1	<1	120	<1	<1	3
1409	08-24-94	2	<1	<1	170	<1	<1	6
1410	08-31-94	2	<1	<1	790	<1	<1	2
1411	09-07-94	<1	<1	<1	280	<1	<1	3
1412	09-15-94	2	<1	<1	200	<1	<1	3

Table 5. Results of chemical analyses for metals and trace constituents in ground water in Valley Forge National Historical Park and vicinity, Montgomery County, Pa.—Continued

Well identification number	Date	Cobalt, dissolved (µg/L as Co)	Copper, dissolved (µg/L as Cu)	Iron, dissolved (µg/L as Fe	Lead, dissolved (µg/L as Pb)	Manganese, dissolved (µg/L as Mn)	Mercury, dissolved (µg/L as Hg)
1161	09-01-94	<1	1	<3	1	<1	<0.1
1162	08-30-94	<1	2	<3	1	<1	<.1
1163	09-01-94	<1	11	<3	2	<1	<.1
1352	09-13-94	<1	2	8	<1	<1	<.1
1368	08-29-94	<1	14	6	<1	<1	<.1
1390	08-30-94	<1	74	<3	2	<1	<.1
1392	08-29-94	<1	5	<3	<1	<1	<.1
1393	09-14-94	<1	36	7	6	4	<.1
1395	08-16-94	<1	20	8	1	8	<.1
1397	08-16-94	<1	1	5	<1	4	<.1
1399	08-18-94	<1	13	61	1	1	<.1
1400	08-22-94	<1	<1	7	<1	15	<.1
1403	08-25-94	<1	50	8	<1	4	<.1
1404	09-14-94	<1	68	11	<1	<1	<.1
1405	09-08-94	<1	3	<3	1	<1	<.1
1408	08-17-94	<1	140	4	1	7	<.1
1409	08-24-94	<1	9	5	<1	<1	<.1
1410	08-31-94	<1	38	39	2	9	<.1
1411	09-07-94	<1	31	<3	2	<1	<.1
1412	09-15-94	<1	23	<3	<1	<1	<.1

Well identification number	Date	Molybdenum, dissolved (µg/L as Mo)	Nickel, dissolved (µg/L as Ni)	Selenium, dissolved (µg/L as Se)	Silver, dissolved (µg/L as Ag)	Uranium, dissolved (µg/L as U)	Zinc, dissolved (µg/L as Zn)
1161	09-01-94	<1	1	<1	<1	2	4
1162	08-30-94	<1	<1	<1	<1	2	2
1163	09-01-94	<1	<1	<1	<1	6	7
1352	09-13-94	<1	<1	1	<1	<1	2
1368	08-29-94	<1	1	<1	<1	1	5
1390	08-30-94	<1	<1	2	<1	<1	6
1392	08-29-94	<1	<1	<1	<1	<1	3
1393	09-14-94	<1	2	<1	<1	<1	7
1395	08-16-94	<1	<1	<1	<1	<1	81
1397	08-16-94	<1	<1	<1	<1	<1	120
1399	08-18-94	<1	3	3	<1	<1	49
1400	08-22-94	2	<1	<1	<1	6	72
1403	08-25-94	<1	3	<1	<1	9	5
1404	09-14-94	<1	1	<1	<1	1	260
1405	09-08-94	<1	<1	<1	<1	1	2
1408	08-17-94	<1	2	<1	<1	<1	20
1409	08-24-94	<1	<1	<1	<1	<1	16
1410	08-31-94	<1	8	<1	<1	<1	54
1411	09-07-94	<1	1	<1	<1	<1	2
1412	09-15-94	<1	2	1	<1	3	2

Radon-222

Although radionuclides occur naturally in the ground water of Valley Forge National Historical park and vicinity, elevated radionuclide activities may present a health problem. Radioactivity is the release of energy and energetic particles by changes in the structure of certain unstable elements as they break down to form more stable arrangements. The most commonly used unit for radioactivity in water is picoCuries per liter. One Curie is the activity of 1 gram of radium, which is equal to 3.7×10^{10} atomic disintegrations per second. Activity refers to the number of particles emitted by a radionuclide. The rate of decay is proportional to the number of atoms present and inversely proportional to half-life.

Naturally occurring radioactivity in ground water is produced primarily by the radioactive decay of uranium-238 and thorium-232. They disintegrate in steps, forming a series of radioactive nuclide “daughter” products, mostly short lived, until a stable lead isotope is produced. The uranium-238 decay series produces the greatest amount of radioactivity in natural ground water. Uranium-238 has a half-life of 4.5×10^9 years. Its daughter products include radium-226 (half-life 1,620 years) and radon-222 (half-life 3.8 days). Radon-222 is a decay product of radium-226 and is a colorless, odorless, inert, alpha-particle-emitting gas, which is water soluble. The end product of the decay series is the stable isotope lead-206.

Ground-water samples for analysis for dissolved radon-222 were collected from 21 wells. Data are given in table 2. The median radon-222 activity of the samples was 1,200 pCi/L, and radon-222 activities ranged from 740 to 5,000 pCi/L. The USEPA has not yet established an MCL for radon-222.

Organic Constituents

One of the most serious consequences of urbanization has been the introduction of man-made organic compounds into the subsurface environment. Some of these compounds have been entering the ground-water system for decades, but awareness of their presence in drinking-water supplies did not begin until the mid-1970’s, when analytical techniques became available to detect their presence. The USEPA has classified 113 compounds, known as priority pollutants, as toxic organic compounds. These compounds are divided into four fractions by gas chromatography-mass spectroscopy analysis: (1) volatile compounds, (2) acid compounds, (3) base-neutral compounds, and (4) pesticides. Wells in the study area were sampled for VOC’s and pesticides.

Volatile Organic Compounds

VOC’s are extensively used in industrial, commercial, and household applications. Their presence in ground water poses a serious problem for public water suppliers, industries, and domestic well owners that rely on ground water. Many of the VOC’s are confirmed or suspected human or animal carcinogens (Council on Environmental Quality, 1981, p. 64). USEPA MCL’s are set for only a few VOC’s (table 3). VOC’s generally enter the ground-water system by spills, leakage from storage tanks, discharge from septic systems, and from lagoons and disposal sites. Once in the ground-water system, VOC’s are difficult to remove, and treatment generally is expensive.

VOC’s have been in use for many years. The length of time VOC’s have been present in the ground water is unknown. Trichloroethylene (TCE), a commercial solvent and industrial metal degreaser, became a common degreasing agent in the 1920’s, and its use in the dry cleaning industry began in the 1930’s. Awareness of its presence in ground water began in the late 1970’s.

Water samples for analysis for VOC’s were collected from 21 wells. Compounds detected, maximum concentrations detected, and number of detections are summarized in table 6. Laboratory analyses are given in table 11. Concentrations of the compounds detected did not exceed USEPA MCL’s. However, the presence of these compounds in ground water indicates a ground-water contamination problem.

VOC’s were detected in water from 16 of the 21 wells (76 percent) sampled. Concentrations of most VOC’s were relatively low; the maximum concentration detected was 5.8 µg/L of chloroform.

Table 6. Volatile organic compounds detected in ground water in Valley Forge National Historical Park and vicinity, Montgomery County, Pa.

Compound	Number of wells in which compound was detected	Maximum concentration detected (micrograms per liter)
Chloroform	11	5.8
1,1-Dichloroethane	3	.3
1,1-Dichloroethylene	2	.3
Methylene chloride	1	.7
Methylchloride	1	.3
Methyl tert-butyl ether (MTBE)	5	3.3
Tetrachloroethylene (PCE)	3	1.3
Trichlorofluoromethane (Freon-11)	1	.5
1,1,1-Trichloroethane (TCA)	4	1.5
Trichloroethylene (TCE)	4	2.4
Trichlorotrifluoromethane (Freon-113)	2	.4

The most commonly detected VOC was chloroform. It was detected in water from 52 percent of the wells sampled. Chloroform is a solvent used in many industries, including the chemical, electronics, and pharmaceutical industries. It is widely distributed in the atmosphere and water and is found in most municipal drinking water supplies and in sewage. It is a suspected human carcinogen (Lucius and others, 1992, p. 194-195). Chloroform also is a common laboratory contaminant.

The second most commonly detected compound was methyl tert-butyl ether (MTBE), which was detected in water from 24 percent of wells sampled. MTBE is an oxygenate added to gasoline to increase the octane level and to reduce carbon monoxide and ozone in air. MTBE is a commonly used oxygenate because of its low cost, ease of production, and favorable blending characteristics. It is made from methanol, which is derived primarily from natural gas. Gasoline can contain up to 15 percent MTBE by volume. MTBE is volatile and soluble in water; therefore, it can be expected to be found in both air and water.

Many of the VOC's detected in the ground water are industrial solvents. TCE, tetrachloroethylene (PCE), and 1,1,1-trichloroethane (TCA) are commonly used as degreasers in the metals, electronics, and plastics industries. TCE also has been used as a septic tank cleaner and a solvent for paints and varnishes and has been used extensively in the dry cleaning, chemical, and pharmaceutical industries. PCE commonly is used in dry cleaning, for degreasing metals, and as a solvent for fats, greases, and gums. It is used in many manufacturing processes. TCA is used in many manufacturing processes and is a commonly used solvent in the cold cleaning of metals and plastics. TCA is used as a primary and carrier solvent in spot cleaners, shoe polish, stain repellants, hair sprays, inks, lubricants, and protective coatings. 1,1-Dichloroethane is used as a solvent; a dewaxer of mineral oils; a coupling agent in antiknock gasoline; in paint, varnish, and finish remover; for metal degreasing; and in several manufacturing processes. Some of the VOC's present in the water samples are the result of anaerobic degradation by microorganisms in the subsurface (fig. 5). 1,1-Dichloroethylene is a reductive dehalogenation degradation product of TCE and PCE (Parsons and others, 1984; Vogel and McCarty, 1985; Freedman and Gossett, 1988).

Methylene chloride is used primarily in aerosols, paint removers, chemical processing, metal degreasing, and as a urethane foam blowing agent. Methylene chloride also is a common laboratory contaminant. Methylchloride is used in the manufacture of silicones and other chemicals and as a solvent and propellant. Some methylchloride is produced naturally by forest fires, volcanos, and plants.

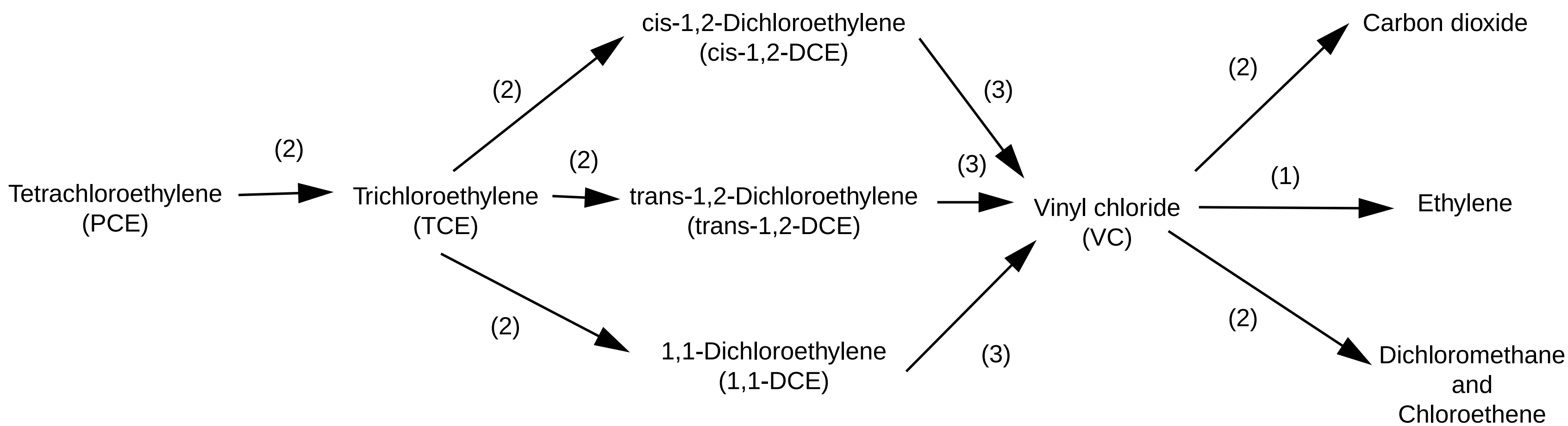


Figure 5. Typical reaction pathways for the anaerobic degradation of tetrachloroethylene and trichloroethylene by reductive dehalogenation. Reactions from: (1) Freeman and Gossett (1989); (2) Parsons and others (1984); and (3) Vogel and McCarty (1985).

Two chlorofluorocarbon (CFC) compounds were detected. Trichlorotrifluoromethane is a CFC also known as Freon-113. It is used primarily as an aerosol propellent but also is used in cleaning fluids and solvents. Trichlorofluoromethane, a CFC known as Freon-11, is used as an aerosol propellant. It also is used in commercial refrigeration and in the manufacture of aerosol sprays, cleaning compounds, solvents, and fire extinguishers.

Pesticides

Pesticides are widely used in both rural and urban areas of Montgomery County. Pesticides are divided into insecticides and herbicides on the basis of their use. Insecticides are used in agricultural areas to control crop-damaging insects and in urban areas to control household and garden insects. Herbicides are used to control weeds that compete with crops in agricultural areas and home gardens. They also are used to control broad-leaf weeds on lawns and turf and to defoliate utility, railroad, and highway right-of-ways.

Organochlorine insecticides

Organochlorine insecticides have low solubility in water, are persistent in the environment, and are strongly bioaccumulated by many organisms. The use of many organochlorine insecticides has been prohibited or restricted by the USEPA.

Water samples from 12 wells were analyzed for organochlorine insecticides. Complete laboratory analyses are given in table 7. Five organochlorine insecticides were found in concentrations above the detection limit: chlordane, DDD, dieldrin, endrin, and heptachlor epoxide. MCL's are set for only a few organochlorine insecticides (table 3). Concentrations of chlordane, endrin, and heptachlor epoxide detected in water samples did not exceed USEPA MCL's. The USEPA has not set an MCL for DDD or dieldrin.

Dieldrin and heptachlor epoxide were the most frequently detected organochlorine insecticides; they were detected in water from three wells or 25 percent of wells sampled. Dieldrin is an isomer of endrin. It has been used as a contact insecticide to control corn pests, soil pests, termites, and many other pests. All uses of dieldrin were prohibited by the USEPA in 1973, and it is no longer manufactured in the United States. Heptachlor oxidizes to heptachlor epoxide in the soil. The use of heptachlor was restricted by the USEPA in 1983 to subsurface termite control. It is injected into the subsurface outside of dwellings and other buildings.

Chlordane and DDD were the second most frequently detected insecticides; they were detected in water from two wells or 17 percent of wells sampled. DDD, also known as TDE, was formerly manufactured as an insecticide. All uses of DDD were prohibited by the USEPA in 1973, and it is no longer manufactured in the United States. DDD is a breakdown product of DDT formed by reductive dehalogenation. Chlordane is a non-systematic, broad spectrum insecticide that was used for termite control in homes and gardens and for soil insects for crop protection. The use of chlordane was restricted by the USEPA in 1980 to commercial termite control; it is no longer available to the general public.

Endrin was detected in a water sample from one well. Endrin is used to control insects on grain crops, for grasshopper control on noncrop lands, and as a rodenticide in orchards.

Table 7. Results of chemical analyses for organochlorine insecticides in ground water in Valley Forge National Historical Park and vicinity, Montgomery County, Pa.

[Concentrations in micrograms per liter; <, less than]

Well identification number	Date	Aldrin, total	Chlordane, total	DDD, total	DDE, total	DDT, total	Dieldrin, total
1161	09-01-94	<0.001	0.1	0.001	<0.001	<0.001	0.060
1162	08-30-94	<.001	<.1	<.001	<.001	<.001	.020
1163	09-01-94	<.001	<.1	<.001	<.001	<.001	.001
1352	09-13-94	<.001	<.1	<.001	<.001	<.001	<.001
1395	08-16-94	<.001	<.1	<.001	<.001	<.001	<.001
1397	08-16-94	<.001	<.1	<.001	<.001	<.001	<.001
1399	08-18-94	<.001	<.1	<.001	<.001	<.001	<.001
1400	08-22-94	<.001	<.1	<.001	<.001	<.001	<.001
1403	08-25-94	<.001	.1	.002	<.001	<.001	<.001
1408	08-17-94	<.001	<.1	<.001	<.001	<.001	<.001
1411	09-07-94	<.001	<.1	<.001	<.001	<.001	<.001
1412	09-15-94	<.001	<.1	<.001	<.001	<.001	<.001

Well identification number	Date	Endosulfan, total	Endrin, total	Heptachlor, total	Heptachlor epoxide, total	Lindane, total	Methoxychlor, total
1161	09-01-94	<0.001	<0.001	<0.001	0.006	<0.001	<0.01
1162	08-30-94	<.001	<.001	<.001	.002	<.001	<.01
1163	09-01-94	<.001	<.001	<.001	<.001	<.001	<.01
1352	09-13-94	<.001	<.001	<.001	<.001	<.001	<.01
1395	08-16-94	<.001	.001	<.001	<.001	<.001	<.01
1397	08-16-94	<.001	<.001	<.001	<.001	<.001	<.01
1399	08-18-94	<.001	<.001	<.001	<.001	<.001	<.01
1400	08-22-94	<.001	<.001	<.001	<.001	<.001	<.01
1403	08-25-94	<.001	<.001	<.001	.004	<.001	<.01
1408	08-17-94	<.001	<.001	<.001	<.001	<.001	<.01
1411	09-07-94	<.001	<.001	<.001	<.001	<.001	<.01
1412	09-15-94	<.001	<.001	<.001	<.001	<.001	<.01

Well identification number	Date	Mirex, total	Perthane, total	Toxaphene, total	PCB, total	PCN, total
1161	09-01-94	<0.01	<0.1	<1	<0.1	<0.1
1162	08-30-94	<.01	<.1	<1	<.1	<.1
1163	09-01-94	<.01	<.1	<1	<.1	<.1
1352	09-13-94	<.01	<.1	<1	<.1	<.1
1395	08-16-94	<.01	<.1	<1	<.1	<.1
1397	08-16-94	<.01	<.1	<1	<.1	<.1
1399	08-18-94	<.01	<.1	<1	<.1	<.1
1400	08-22-94	<.01	<.1	<1	<.1	<.1
1403	08-25-94	<.01	<.1	<1	<.1	<.1
1408	08-17-94	<.01	<.1	<1	<.1	<.1
1411	09-07-94	<.01	<.1	<1	<.1	<.1
1412	09-15-94	<.01	<.1	<1	<.1	<.1

Organophosphorus insecticides

Organophosphorus insecticides have been used as substitutes for the banned organochlorine insecticides because they are less persistent in the environment and more selective in their targets. Water samples from 12 wells were analyzed for diazinon, ethion, malathion, methyl parathion, parathion, and trithion. None of these insecticides were detected. Laboratory analyses are given in table 8.

Table 8. Results of chemical analyses for organophosphorus insecticides in ground water in Valley Forge National Historical Park and vicinity, Montgomery County, Pa.

[Concentrations in micrograms per liter; <, less than]

Well identification number	Date	Diazinon, total	Ethion, total	Malathion, total	Methyl parathion, total	Parathion, total	Trithion, total
1161	09-01-94	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
1162	08-30-94	<.01	<.01	<.01	<.01	<.01	<.01
1163	09-01-94	<.01	<.01	<.01	<.01	<.01	<.01
1352	09-13-94	<.01	<.01	<.01	<.01	<.01	<.01
1395	08-16-94	<.01	<.01	<.01	<.01	<.01	<.01
1397	08-16-94	<.01	<.01	<.01	<.01	<.01	<.01
1399	08-18-94	<.01	<.01	<.01	<.01	<.01	<.01
1400	08-22-94	<.01	<.01	<.01	<.01	<.01	<.01
1403	08-25-94	<.01	<.01	<.01	<.01	<.01	<.01
1408	08-17-94	<.01	<.01	<.01	<.01	<.01	<.01
1411	09-07-94	<.01	<.01	<.01	<.01	<.01	<.01
1412	09-15-94	<.01	<.01	<.01	<.01	<.01	<.01

Organonitrogen herbicides

Organonitrogen herbicides mainly are used for preemergence applications on corn, soybeans, and other crops for control of annual grasses and broadleaf weeds. Water samples from 12 wells were analyzed for the herbicides listed in table 9. Simazine was detected at a concentration of 0.1 μg/L in water from well MG-1399; the concentration of simazine in the sample did not exceed the USEPA MCL (table 3). Simazine is used to control annual grasses and broadleaf weeds in corn, alfalfa, and other crops and on fairways, lawns, and turf. In higher concentrations, it is used for nonselective control of weeds along right-of-ways and on industrial sites.

Table 9. Results of chemical analyses for organonitrogen herbicides in ground water in Valley Forge National Historical Park and vicinity, Montgomery County, Pa.

[Concentrations in micrograms per liter; <, less than]

Well identification number	Date	Alachlor, total	Ametryne, total	Atrazine, total	Bromacil, total	Butachlor, total	Butylate, total
1161	09-01-94	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1
1162	08-30-94	<.1	<.1	<.1	<.2	<.1	<.1
1163	09-01-94	<.1	<.1	<.1	<.2	<.1	<.1
1352	09-13-94	<.1	<.1	<.1	<.2	<.1	<.1
1395	08-16-94	<.1	<.1	<.1	<.2	<.1	<.1
1397	08-16-94	<.1	<.1	<.1	<.2	<.1	<.1
1399	08-18-94	<.1	<.1	<.1	<.2	<.1	<.1
1400	08-22-94	<.1	<.1	<.1	<.2	<.1	<.1
1403	08-25-94	<.1	<.1	<.1	<.2	<.1	<.1
1408	08-17-94	<.1	<.1	<.1	<.2	<.1	<.1
1411	09-07-94	<.1	<.1	<.1	<.2	<.1	<.1
1412	09-15-94	<.1	<.1	<.1	<.2	<.1	<.1

Table 9. Results of chemical analyses for organonitrogen herbicides in ground water in Valley Forge National Historical Park and vicinity, Montgomery County, Pa.—Continued

Well identification number	Date	Carboxin, total	Cyanazine, total	Cycloate, total	De-ethyl-atrazine, total	De-isopropyl-atrazine, total	Diphen-amide, total
1161	09-01-94	<0.2	<0.2	<0.1	<0.2	<0.2	<0.1
1162	08-30-94	<.2	<.2	<.1	<.2	<.2	<.1
1163	09-01-94	<.2	<.2	<.1	<.2	<.2	<.1
1352	09-13-94	<.2	<.2	<.1	<.2	<.2	<.1
1395	08-16-94	<.2	<.2	<.1	<.2	<.2	<.1
1397	08-16-94	<.2	<.2	<.1	<.2	<.2	<.1
1399	08-18-94	<.2	<.2	<.1	<.2	<.2	<.1
1400	08-22-94	<.2	<.2	<.1	<.2	<.2	<.1
1403	08-25-94	<.2	<.2	<.1	<.2	<.2	<.1
1408	08-17-94	<.2	<.2	<.1	<.2	<.2	<.1
1411	09-07-94	<.2	<.2	<.1	<.2	<.2	<.1
1412	09-15-94	<.2	<.2	<.1	<.2	<.2	<.1

Well identification number	Date	Hexazinone, total	Metolachlor, total	Metribuzen, total	Prometone, total	Prometryne, total	Propachlor, total
1161	09-01-94	<0.2	<0.2	<0.10	<0.2	<0.10	<0.10
1162	08-30-94	<.2	<.2	<.1	<.2	<.1	<.1
1163	09-01-94	<.2	<.2	<.1	<.2	<.1	<.1
1352	09-13-94	<.2	<.2	<.1	<.2	<.1	<.1
1395	08-16-94	<.2	<.2	<.1	<.2	<.1	<.1
1397	08-16-94	<.2	<.2	<.1	<.2	<.1	<.1
1399	08-18-94	<.2	<.2	<.1	<.2	<.1	<.1
1400	08-22-94	<.2	<.2	<.1	<.2	<.1	<.1
1403	08-25-94	<.2	<.2	<.1	<.2	<.1	<.1
1408	08-17-94	<.2	<.2	<.1	<.2	<.1	<.1
1411	09-07-94	<.2	<.2	<.1	<.2	<.1	<.1
1412	09-15-94	<.2	<.2	<.1	<.2	<.1	<.1

Well identification number	Date	Propazine, total	Simazine, total	Simetryne, total	Terbacil, total	Trifluralin, total	Vernolate, total
1161	09-01-94	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1
1162	08-30-94	<.1	<.1	<.1	<.2	<.1	<.1
1163	09-01-94	<.1	<.1	<.1	<.2	<.1	<.1
1352	09-13-94	<.1	<.1	<.1	<.2	<.1	<.1
1395	08-16-94	<.1	<.1	<.1	<.2	<.1	<.1
1397	08-16-94	<.1	<.1	<.1	<.2	<.1	<.1
1399	08-18-94	<.1	.1	<.1	<.2	<.1	<.1
1400	08-22-94	<.1	<.1	<.1	<.2	<.1	<.1
1403	08-25-94	<.1	<.1	<.1	<.2	<.1	<.1
1408	08-17-94	<.1	<.1	<.1	<.2	<.1	<.1
1411	09-07-94	<.1	<.1	<.1	<.2	<.1	<.1
1412	09-15-94	<.1	<.1	<.1	<.2	<.1	<.1

Other Organic Compounds

Determinations were made for gross polychlorinated biphenyls (PCB's) and gross polychlorinated napthalenes (PCN's) in water samples from 12 wells inside the park boundary. Laboratory analyses are given in table 7. PCB's and PCN's were not detected in any of the water samples.

SUMMARY

Valley Forge National Historical Park is just south of the CSG Superfund Site. Industrial activities at the CSG Site have contaminated ground water in the vicinity of the site with volatile organic compounds (VOC's). The CSG Site is not the only source of VOC contamination in the area. The 7.5-mi^2 study area includes the part of Valley Forge National Historical Park in Lower Providence and West Norriton Townships in Montgomery County, Pa., and surrounding vicinity.

Valley Forge National Historical Park is underlain by sedimentary rocks of the Upper Triassic age Stockton Formation, which form a complex, heterogeneous, multiaquifer system. This aquifer system comprises a series of gently dipping lithologic units—conglomerates, sandstones, and shales—with different hydraulic properties. In the Stockton Formation, ground water in the weathered zone moves through intergranular openings that have formed as a result of weathering. Ground water in the unweathered zone mainly moves through a network of interconnected secondary openings—fractures, bedding planes, and joints. In general, the sandstone and conglomerate units are the principal water-bearing units, but some of the siltstone and shale units may contain water-bearing openings. Ground water is unconfined in the shallower part of the aquifer and confined or semiconfined in the deeper part of the aquifer.

A potentiometric-surface map of the study area shows a cone of depression approximately 0.5 mi in diameter, centered near the CSG Site. The cone of depression is caused by the pumping of six public supply wells, which has resulted in the formation of a ground-water divide between the cone of depression and Valley Forge National Historical Park. The ground-water divide provides a hydraulic barrier to the flow of ground water and contaminants from the CSG Site to the park. Ground water in the cone of depression discharges to pumping wells in the cone of depression. If pumping within the cone of depression was to cease, water levels would recover, and the ground-water divide would shift northward toward the topographic high and ground-water mound south of Egypt Road. If this shift was to occur, a hydraulic gradient would be established between the CSG Site and the Schuylkill River, the point of ground-water discharge. Contaminated ground water would flow down the hydraulic gradient toward the park.

Water samples were collected from 12 wells within the park boundary and 9 wells between the park boundary and the ground-water divide to the north of the park. The wells sampled outside the park boundary were selected because of known or suspected ground-water contamination. All water samples were analyzed for physical properties (field determinations), nutrients, common ions, metals and other trace constituents, and VOC's. Water samples from the 12 wells inside the park boundary also were analyzed for pesticides. Concentrations of inorganic constituents (nutrients, common ions, metals and other trace constituents) in the water samples did not exceed USEPA MCL's. The water from one well (MG-1368) exceeded the USEPA SMCL for TDS. The median radon-222 activity of the 21 water samples was 1,200 pCi/L, and radon-222 activities ranged from 740 to 5,000 pCi/L. The USEPA has not set an MCL for radon-222.

Very low concentrations of organic compounds were detected in some of the water samples. VOC's were detected in water from 16 of the 21 wells (76 percent) sampled; the maximum concentration detected was 5.8 µg/L of chloroform. The most commonly detected VOC was chloroform. The second most commonly detected compound was MTBE, which was detected in water from 24 percent of wells sampled. MTBE is an oxygenate added to gasoline to increase the octane level and to reduce carbon monoxide and ozone in air. MCL's are set by the USEPA for only a few VOC's and pesticides. Concentrations of the compounds detected did not exceed USEPA MCL's. However, the presence of these compounds in ground water indicates a ground-water contamination problem. Several pesticides were detected in water samples collected from within the park boundaries: chlordane, DDD, dieldrin, endrin, heptachlor epoxide, and simazine. Concentrations of the detected pesticides were 0.1 µg/L or less, and did not exceed USEPA MCL's.

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Table 10. Record of wells, Valley Forge National Historical Park and vicinity, Montgomery County, Pa.

Site identification number: Well location. First six numbers are latitude in degrees, minutes, and seconds. Next seven numbers are longitude in degrees, minutes, and seconds. Last two numbers are sequence number

Use of site: 0, observation well; U, unused; W, withdrawal

Use of water: C, commercial; H, domestic; I, irrigation; N, industrial; P, public supply; T, institutional; U, unused

Elevation of land surface is estimated from topographic maps. Datum is National Geodetic Vertical Datum of 1929

Water-bearing zones: Depth in feet below land surface

Water level: Depth to water in feet below land surface

Status during measurement: M measured static water level; P, pumping water level; R, reported

Specific capacity: Given in gallons per minute per foot of drawdown

Table 10. Record of wells, Valley Forge National Historical Park and vicinity, Montgomery County, Pa..—Continued

Well identification number	Site identification number	Owner	Driller	Date drilled	Use of site	Use of water
768	400738075254401	Audubon Water Co.	--	--	U	P
769	400736075254301	Audubon Water Co.	--	--	U	P
770	400717075252501	Audubon Water Co.	--	--	W	P
793	400703075270401	St. Gabriels Hall	Ridpath	08-13-1929	W	T
794	400704075270501	St. Gabriels Hall	Ridpath	12-06-1929	W	T
800	400728075250201	Valley Forge Corporate Center	Kohl Brothers	10-30-1963	W	N
873	400721075244101	Valley Forge Corporate Center	Kohl Brothers	02-12-1959	W	N
874	400720075245801	Valley Forge Corporate Center	Kohl Brothers	08-01-1960	W	N
968	400724075251401	Valley Forge Corporate Center	--	01-01-1971	W	N
1063	400718075252501	Audubon Water Co.	--	--	W	P
1161	400650075252001	Valley Forge Home Park	--	--	W	C
1162	400645075252501	Valley Forge Home Park	--	--	W	C
1163	400641075252801	Valley Forge Home Park	--	--	W	C
1317	400742075251501	General Washington CC	--	09-25-1961	W	I
1351	400715075255501	Knickerbocker, Sue	--	--	U	H
1352	400710075260001	Wallace, David	Garber and Sons Inc.	05-1990	W	H
1354	400720075254601	Dininniy, Jeffrey	Charles Lauman	09-1992	W	H
1355	400720075260301	Achey, William	Miller Pump	1962	W	H
1356	400713075255702	Wallace, R.	--	05-01-1954	W	H
1357	400709075253901	Carrio, Mark	Charles Lauman	09-23-1976	W	H
1358	400712075253601	Cotteta	Charles Lauman	08-1962	W	H
1359	400743075245801	Casselberry, Howard	Hardin-Huber	02-24-1993	O	U
1360	400718075255401	Huber, John	Miller Pump	12-1990	W	H
1361	400658075252001	Fulmer, Hiram	Hardin-Huber	02-22-1993	O	U
1362	400729075261301	Pavarati, Frank	--	--	W	H
1363	400728075262001	Supulski, Louise	Miller Pump	1954	W	H
1364	400722075260901	Rosen, William	--	1992	W	H
1365	400728075255501	Kip, Mary Louise	Miller Pump	08-1972	W	H
1368	400651075250801	Mobil Gas Station	--	1964	W	C
1369	400654075250701	Kahn, Charles	--	1969	W	H
1370	400707075264101	Sofford, Robert	--	--	U	H
1371	400707075264901	Camiel, Nina	Miller Pump	1990	W	H
1372	400722075264001	Audubon, James	--	--	W	H
1373	400649075273401	Mcarthur, William	--	--	W	H
1374	400658075273601	Cahill, John	--	--	W	H
1375	400702075265101	Kershner, Edward	Miller Pump	02-09-1981	W	H
1376	400656075265101	Barbaratta, Albert	Miller Pump	09-1990	W	H
1377	400745075253901	Eicherly, John	Miller Pump	1981	W	H
1378	400654075275101	Baird, Jack	Miller Pump	1982	W	H

Table 10. Record of wells, Valley Forge National Historical Park and vicinity, Montgomery County, Pa.—Continued

Elevation of land surface (feet)	Depth of well (feet)	Depth cased (feet)	Casing diameter (inches)	Water-bearing zones	Water evel (feet)	Status during measure-ment	Date water level measured	Discharge (gallons per minute)	Specific capacity (gpm/ft)	Hours pumped	Well identification number
212	356	--	--	--	97.79	M	06-10-1994	52	3.7	24	768
218	160	56.5	6	--	90.52	M	06-10-1994	40	.45	48	769
187	240	40.5	6	--	86.58	P	06-10-1994	175	2.5	72	770
167	445	65	8	--	64.38	M	06-14-1994	87	--	--	793
167	500	62	8	--	62.22	M	06-14-1994	85	.80	23	794
227	400	55	8	70, 150, 250, 300	134.88	P	06-10-1994	110	--	--	800
		45	12					110	.52	24	
217	400	54	8	60, 210, 285	39	M	02-12-1959	119	.62	24	873
		37	12								
200	400	62	8	--	134.48	R	06-10-1994	245	1.5	24	874
		27	12								
205	405	36	8	60, 75, 150, 178	54.28	P	06-10-1994	412	--	48	968
		23	12	265, 285, 300, 350							
188	404	38	8	--	--	--	--	--	--	--	1063
		21	12								
152	298	40	8	--	--		--	--	--	--	1161
		60	6								
141	145	--	--	--	69.06	M	06-15-1994	--	--	--	1162
139	190	--	--	--	76.58	M	06-15-1994	--	--	--	1163
224	300	8	--	65, 115, 180	43.48	R	06-02-1994	--	--	--	1317
194	--	--	--	--	46.92	M	05-20-1994	--	--	--	1351
181	147	65	6	67, 80, 100, 137	42.04	M	05-24-1994	60	.59	.5	1352
199	362	45	6		56.62	M	05-24-1994	--	--	--	1354
175	110	40	6	--	26.40	M	05-25-1994	--	--	--	1355
190	93	33.5	6	--	48.08	M	05-24-1994	33	--	--	1356
174	195	50	6	60, 188	51.02	M	05-27-1994	50	--	--	1357
193	222	42	6	--	76.06	M	05-25-1994	--	--	--	1358
236	250	30	8	66, 225, 250	100.28	M	05-31-1994	--	--	--	1359
		225	4								
192	260	80	6	--	52.32	M	06-01-1994	--	--	--	1360
180	250	30	8	60	70.34	M	06-01-1994	--	--	--	1361
		225	4	90, 225-250							
203	--	--	6	--	66.96	M	06-02-1994	--	--	--	1362
200	--	--	6	--	87.67	M	06-02-1994	--	--	--	1363
189	--	--	6	--	37.38	M	06-02-1994	--	--	--	1364
210	218	40	6	170	65.28	M	06-02-1994	5	--	--	1365
165	--	--	6	--	64.88	M	06-03-1994	--	--	--	1368
179	--	--	6	--	72.40	M	06-03-1994	--	--	--	1369
192	51.4	--	--	--	42.94	M	06-06-1994	--	--	--	1370
183	--	--	6	--	39.88	M	06-06-1994	--	--	--	1371
153	--	--	6	--	62.28	M	06-07-1994	--	--	--	1372
133	--	--	6	--	15.28	M	06-08-1994	--	--	--	1373
155	--	--	6	--	58.13	M	06-02-1994	--	--	--	1374
162	175	61	6	--	19.62	M	06-10-1994	15	--	--	1375
161	222	84	6	--	26.28	M	06-10-1994	20	--	--	1376
205	320	--	6	--	68.02	M	06-10-1994	30	--	--	1377
130	300	--	6	--	41.52	M	06-10-1994	14	--	--	1378

Table 10. Record of wells, Valley Forge National Historical Park and vicinity, Montgomery County, Pa..—Continued

Well identification number	Site identification number	Owner	Driller	Date drilled	Use of site	Use of water
1379	400652075275201	Baird, Harold	Miller Pump	1969	W	H
1380	400743075250001	Casselberry, Howard	Charles Lauman	08-12-1976	W	H
1381	400743075245601	Beaver Construction Co.	Miller Pump	10-1980	W	H
1382	400715075254601	Kuhnsman, Robert	Meyers	1963	W	H
1383	400659075260201	Schwoebel	--	--	W	H
1384	400653075264601	Salvino, George	--	--	W	H
1385	400653075251401	Philadelphia Electric Co.	--	--	W	H
1386	400746075245701	Mcnab, Marciella	--	--	W	H
1387	400646075274701	Kinney, William	Miller Pump	1983	W	H
1388	400641075275101	Fort, Robert	--	--	W	H
1389	400643075275401	Rauscher, Coleen	Miller Pump	--	W	H
1390	400642075280701	Oconnor, Kevin	--	1948	W	H
1391	400646075280401	Conniere, Anna	Miller Pump	1974	W	H
1392	400651075280601	Mckeon, Cortland	Miller Pump	--	W	H
1393	400655075251601	Protect A Life Buglar Alarm	--	--	W	H
1394	400659075252101	Heckert, George	Miller Pump	10-1988	W	C
1395	400634075273701	Valley Forge Park, Tenant House	B.L. Meyers	--	W	H
1396	400742075254701	Beswick, T.	Charles Lauman	--	W	H
1397	400637075272801	Valley Forge Park, Springhouse	--	1989	W	H
1398	400650075275801	Valley Forge Garage	--	--	W	H
1399	400634075252401	Valley Forge National Park	--	--	W	P
1400	400638075251701	Valley Forge National Park	Garber	12-1984	W	P
1401	400702075274701	Diegel, Robert	Brookover	1960	W	H
1402	400659075275901	Sullivan, Dan	--	--	W	H
1403	400643075251901	Kelly	--	--	W	H
1404	400659075252501	Colonial Penn Insurance Co.	Garber	08-1984	W	C
1405	400703075253601	Lamb, Walter	--	--	W	H
1406	400703075273601	Procetto, Anne	Miller Pump	--	W	H
1408	400642075251801	Highley, Maryann	--	--	W	H
1409	400657075252001	Fulmer, Hiram	--	--	W	H
1410	400704075265001	Capparella, Patsy	--	--	W	H
1411	400738075263601	Sofford, Robert	--	--	W	H
1412	400713075255801	Rothrock and Payne	Bollinger	05-1985	W	H

Table 10. Record of wells, Valley Forge National Historical Park and vicinity, Montgomery County, Pa.—Continued

Elevation of land surface (feet)	Depth of well (feet)	Depth cased (feet)	Casing diameter (inches)	Water-bearing zones	Water evel (feet)	Status during measure-ment	Date water level measured	Discharge (gallons per minute)	Specific capacity (gpm/ft)	Hours pumped	Well identification number
120	110	40	6	--	22.23	M	06-10-1994	25	--	--	1379
240	221	45	6	96, 135	53.12	M	05-31-1994	15	--	--	1380
238	320	60	6	300	68.84	M	05-31-1994	15	--	--	1381
135	80	--	6		60.20	M	06-16-1994	22	--	--	1382
139	--	--	6	--	22.48	M	06-24-1994	--	--	--	1383
151	--	--	--	--	19.38	M	06-14-1994	--	--	--	1384
177	--	--	6	--	56.80	M	06-24-1994	--	--	--	1385
249	--	--	6	--	89.88	M	06-20-1994	--	--	--	1386
148	--	--	6	--	52.14	M	06-14-1994	--	--	--	1387
142	96	--	6	--	56.44	M	06-14-1994	--	--	--	1388
148	300	--	6	--	65.26	M	06-14-1994	--	--	--	1389
105	--	--	6	--	29.32	M	06-14-1994	--	--	--	1390
113	--	--	6	--	39.14	R	06-14-1994	--	--	--	1391
88	222	--	6	--	9.36	M	06-14-1994	--	--	--	1392
180	--	--	--	--	37.90	M	06-10-1994	--	--	--	1393
173	130	--	6	--	53.06	M	06-29-1994	--	--	--	1394
140	530	--	6	--	55.01	M	06-15-1994	14	0.12	--	1395
200	222	60	6	150, 180	82.66	M	06-09-1994	60	--	--	1396
115	--	--	6	--	26.06	M	06-15-1994	--	--	--	1397
115	--	--	6	--	34.94	M	06-15-1994	--	--	--	1398
80	500	--	--	--	18.23	M	06-15-1994	--	--	--	1399
100	497	123	6	232, 345, 485	52.06	M	06-16-1994	10	.02	0.5	1400
138	109	20	6	--	68.48	M	06-20-1994	--	--	--	1401
94	--	--	6	--	29.17	M	06-21-1994	--	--	--	1402
149	282	--	--	--	79.28	M	06-21-1994	--	--	--	1403
163	207	42	6	--	49.06	M	06-21-1994	45	--	--	1404
150	85	--	--	--	32.14	M	06-20-1994	--	--	--	1405
157	--	--	6	--	84.74	M	06-29-1994	--	--	--	1406
142	--	--	--	--	--		--	--	--	--	1408
182	120	--	--	--	--		--	--	--	--	1409
168	--	--	--	--	--		--	--	--	--	1410
190	225	--	--	--	--		--	--	--	--	1411
187	170	42	6	122, 146, 160	63.28	M	09-15-1994	30	--	--	1412

Table 11. Results of chemical analyses for volatile organic compounds in ground water in Valley Forge National Historical Park and vicinity, Montgomery County, Pa.

[Concentrations in micrograms per liter; <, less than; --, no data]

Well identification number	Date	Acrolein, total	Acrylonitrile, total	Benzene, total	Bromo-benzene, total	Bromo-chloro-methane, total	Bromo-dichloro-methane, total	Bromoform, total
1161	09-01-94	<20	<20	<0.2	<0.2	<0.2	<0.2	<0.2
1162	08-30-94	<20	<20	<.2	<.2	<.2	<.2	<.2
1163	09-01-94	<20	<20	<.2	<.2	<.2	<.2	<.2
1352	09-13-94	--	--	<.2	<.2	<.2	<.2	<.2
1368	08-29-94	<20	<20	<.2	<.2	<.2	<.2	<.2
1384	08-24-94	<20	<20	<.2	<.2	<.2	<.2	<.2
1390	08-30-94	<20	<20	<.2	<.2	<.2	<.2	<.2
1392	08-29-94	<20	<20	<.2	<.2	<.2	<.2	<.2
1393	09-14-94	--	--	<.2	<.2	<.2	<.2	<.2
1395	08-16-94	<20	<20	<.2	<.2	<.2	<.2	<.2
1397	08-16-94	<20	<20	<.2	<.2	<.2	<.2	<.2
1399	08-18-94	<20	<20	<.2	<.2	<.2	<.2	<.2
1400	08-22-94	<20	<20	<.2	<.2	<.2	<.2	<.2
1403	08-25-94	<20	<20	<.2	<.2	<.2	<.2	<.2
1404	09-14-94	--	--	<.2	<.2	<.2	<.2	<.2
1405	09-08-94	<20	<20	<.2	<.2	<.2	<.2	<.2
1408	08-17-94	<20	<20	<.2	<.2	<.2	<.2	<.2
1409	08-24-94	<20	<20	<.2	<.2	<.2	<.2	<.2
1410	08-31-94	<20	<20	<.2	<.2	<.2	<.2	<.2
1411	09-07-94	<20	<20	<.2	<.2	<.2	<.2	<.2
1412	09-15-94	--	--	<.2	<.2	<.2	<.2	<.2

Well identification number	Date	Bromo-methane, total	n-Butyl-benzene, total	Carbon tetracloride, total	Chloro-benzene, total	Chloro-ethane, total	2-Chloro-ethylvinyl ether, total	Chloroform, total
1161	09-01-94	<0.2	<0.2	<0.2	<0.2	<0.2	<1	1.0
1162	08-30-94	<.2	<.2	<.2	<.2	<.2	<1	.6
1163	09-01-94	<.2	<.2	<.2	<.2	<.2	<1	<.2
1352	09-13-94	<.2	<.2	<.2	<.2	<.2	<1	.5
1368	08-29-94	<.2	<.2	<.2	<.2	<.2	<1	.6
1384	08-24-94	<.2	<.2	<.2	<.2	<.2	<1	<.2
1390	08-30-94	<.2	<.2	<.2	<.2	<.2	<1	.3
1392	08-29-94	<.2	<.2	<.2	<.2	<.2	<1	<.2
1393	09-14-94	<.2	<.2	<.2	<.2	<.2	<1	3.1
1395	08-16-94	<.2	<.2	<.2	<.2	<.2	<1	<.2
1397	08-16-94	<.2	<.2	<.2	<.2	<.2	<1	<.2
1399	08-18-94	<.2	<.2	<.2	<.2	<.2	<1	<.2
1400	08-22-94	<.2	<.2	<.2	<.2	<.2	<1	<.2
1403	08-25-94	<.2	<.2	<.2	<.2	<.2	<1	1.8
1404	09-14-94	<.2	<.2	<.2	<.2	<.2	<1	1.9
1405	09-08-94	<.2	<.2	<.2	<.2	<.2	<1	<.2
1408	08-17-94	<.2	<.2	<.2	<.2	<.2	<1	.5
1409	08-24-94	<.2	<.2	<.2	<.2	<.2	<1	5.8
1410	08-31-94	<.2	<.2	<.2	<.2	<.2	<1	.2
1411	09-07-94	<.2	<.2	<.2	<.2	<.2	<1	<.2
1412	09-15-94	<.2	<.2	<.2	<.2	<.2	<1	<.2

Table 11. Results of chemical analyses for volatile organic compounds in ground water in Valley Forge National Historical Park and vicinity, Montgomery County, Pa.—Continued

Well identification number	Date	1,2-Chloro-toluene, total	1,4-Chloro-toluene, total	1,2-Dibromo-3-chloro-propane, total	Dibromo-chloro-methane, total	1,2-Dibromo-ethane, total	Dibromo-methane, total	1,2-Dichloro-benzene, total
1161	09-01-94	<0.2	<0.2	<1	<0.2	<0.2	<0.2	<0.2
1162	08-30-94	<.2	<.2	<1	<.2	<.2	<.2	<.2
1163	09-01-94	<.2	<.2	<1	<.2	<.2	<.2	<.2
1352	09-13-94	<.2	<.2	<1	<.2	<.2	<.2	<.2
1368	08-29-94	<.2	<.2	<1	<.2	<.2	<.2	<.2
1384	08-24-94	<.2	<.2	<1	<.2	<.2	<.2	<.2
1390	08-30-94	<.2	<.2	<1	<.2	<.2	<.2	<.2
1392	08-29-94	<.2	<.2	<1	<.2	<.2	<.2	<.2
1393	09-14-94	<.2	<.2	<1	<.2	<.2	<.2	<.2
1395	08-16-94	<.2	<.2	<1	<.2	<.2	<.2	<.2
1397	08-16-94	<.2	<.2	<1	<.2	<.2	<.2	<.2
1399	08-18-94	<.2	<.2	<1	<.2	<.2	<.2	<.2
1400	08-22-94	<.2	<.2	<1	<.2	<.2	<.2	<.2
1403	08-25-94	<.2	<.2	<1	<.2	<.2	<.2	<.2
1404	09-14-94	<.2	<.2	<1	<.2	<.2	<.2	<.2
1405	09-08-94	<.2	<.2	<1	<.2	<.2	<.2	<.2
1408	08-17-94	<.2	<.2	<1	<.2	<.2	<.2	<.2
1409	08-24-94	<.2	<.2	<1	<.2	<.2	<.2	<.2
1410	08-31-94	<.2	<.2	<1	<.2	<.2	<.2	<.2
1411	09-07-94	<.2	<.2	<1	<.2	<.2	<.2	<.2
1412	09-15-94	<.2	<.2	<1	<.2	<.2	<.2	<.2

Well identification number	Date	1,3-Di-chloro-benzene, total	1,4-Di-chloro-benzene, total	1,1-Di-chloro-ethane, total	1,2-Di-chloro-ethane, total	1,1-Di-chloro-ethylene, total	cis-1,2-Dichloro-ethylene, total	trans-1,2-Dichloro-ethylene, total
1161	09-01-94	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1162	08-30-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1163	09-01-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1352	09-13-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1368	08-29-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1384	08-24-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1390	08-30-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1392	08-29-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1393	09-14-94	<.2	<.2	.3	<.2	.3	<.2	<.2
1395	08-16-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1397	08-16-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1399	08-18-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1400	08-22-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1403	08-25-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1404	09-14-94	<.2	<.2	.2	<.2	<.2	<.2	<.2
1405	09-08-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1408	08-17-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1409	08-24-94	<.2	<.2	.3	<.2	.3	<.2	<.2
1410	08-31-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1411	09-07-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1412	09-15-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2

Table 11. Results of chemical analyses for volatile organic compounds in ground water in Valley Forge National Historical Park and vicinity, Montgomery County, Pa.—Continued

Well identification number	Date	1,2-Di-chloro-propane, total	1,3-Di-chloro-propane, total	2,2-Dichloro-propane, total	1,1-Dichloro-propene, total	cis 1,3-Di-chloro-propene, total	trans-1,3-Di-chloro-propene, total	Dichloro-difluoro-methane, total
1161	09-01-94	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1162	08-30-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1163	09-01-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1352	09-13-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1368	08-29-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1384	08-24-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1390	08-30-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1392	08-29-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1393	09-14-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1395	08-16-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1397	08-16-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1399	08-18-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1400	08-22-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1403	08-25-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1404	09-14-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1405	09-08-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1408	08-17-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1409	08-24-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1410	08-31-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1411	09-07-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1412	09-15-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2

Well identification number	Date	Ethyl-benzene, total	Hexa chloro-butadiene, total	Isopropyl-benzene, total	p-Isopropyl-toulene, total	Methylene-chloride, total	Methyl-chloride, total	Methyl tert butyl ether, total
1161	09-01-94	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1162	08-30-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1163	09-01-94	<.2	<.2	<.2	<.2	<.2	<.2	.3
1352	09-13-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1368	08-29-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1384	08-24-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1390	08-30-94	<.2	<.2	<.2	<.2	<.2	<.2	1.1
1392	08-29-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1393	09-14-94	<.2	<.2	<.2	<.2	<.2	<.2	2.6
1395	08-16-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1397	08-16-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1399	08-18-94	<.2	<.2	<.2	<.2	<.2	.3	<.2
1400	08-22-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1403	08-25-94	<.2	<.2	<.2	<.2	.7	<.2	<.2
1404	09-14-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1405	09-08-94	<.2	<.2	<.2	<.2	<.2	<.2	3.3
1408	08-17-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1409	08-24-94	<.2	<.2	<.2	<.2	<.2	<.2	.6
1410	08-31-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1411	09-07-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1412	09-15-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2

Table 11. Results of chemical analyses for volatile organic compounds in ground water in Valley Forge National Historical Park and vicinity, Montgomery County, Pa.--Continued

Well identification number	Date	Naphthalene, total	n-Propylbenzene, total	Sec-butylbenzene, total	Styrene, total	Tert-butylbenzene, total	1,1,1,2-Tetrachloroethane, total	1,1,2,2-Tetrachloroethane, total
1161	09-01-94	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1162	08-30-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1163	09-01-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1352	09-13-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1368	08-29-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1384	08-24-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1390	08-30-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1392	08-29-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1393	09-14-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1395	08-16-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1397	08-16-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1399	08-18-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1400	08-22-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1403	08-25-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1404	09-14-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1405	09-08-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1408	08-17-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1409	08-24-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1410	08-31-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1411	09-07-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1412	09-15-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2

Well identification number	Date	Tetrachloroethylene, total	1,2,3-Trichlorobenzene, total	1,2,4-Trichlorobenzene, total	1,1,1-Trichloroethane, total	1,1,2-Trichloroethane, total	Trichloroethylene, total	Trichlorofluoromethane, total
1161	09-01-94	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1162	08-30-94	1.3	<.2	<.2	.8	<.2	.6	<.2
1163	09-01-94	<.2	<.2	<.2	.6	<.2	<.2	<.2
1352	09-13-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1368	08-29-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1384	08-24-94	<.2	<.2	<.2	<.3	<.2	<.2	<.2
1390	08-30-94	<.2	<.2	<.2	<.2	<.2	.3	<.2
1392	08-29-94	<.2	<.2	<.2	<.2	<.2	.2	<.2
1393	09-14-94	<.2	<.2	<.2	1.2	<.2	<.2	<.2
1395	08-16-94	<.2	<.2	<.2	<.2	<.2	2.4	<.2
1397	08-16-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1399	08-18-94	<.2	<.2	<.2	<.4	<.2	<.2	<.2
1400	08-22-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1403	08-25-94	.9	<.2	<.2	<.2	<.2	<.2	.5
1404	09-14-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1405	09-08-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1408	08-17-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1409	08-24-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2
1410	08-31-94	.2	<.2	<.2	<.2	<.2	<.2	<.2
1411	09-07-94	<.2	<.2	<.2	1.5	<.2	<.2	<.2
1412	09-15-94	<.2	<.2	<.2	<.2	<.2	<.2	<.2